THE EFFECTS OF QUENCHING AND AGING ON THE MECHANICAL AND PHYSICAL PROPERTIES OF RECYCLED AA6061 ALUMINUM CHIPS

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DEDICATED FOR LOVELY PERSON

For my lovely parents,
Mr. Samsi Bin Lan and Mrs. Roziah Binti Tawil,
Your gratitude and sacrificed was unforgettable,
Your inspiration with full of heart.

For my lovely Siblings,
Thank you for yours supportive,
Created some smile when me cried,
Understanding my emotion with fully patience.

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ABSTRACT

At present, the usage of aluminum is widely used. The recycling process is needed to respond to the government's call for a green earth campaign cause of the lack of mineral resources on this earth. The direct recycling method is one of the recycling method to reduces cost and energy consumptions. The aim of this study to determine the effects of quenching and aging on mechanical and physical properties of recycled AA6061 aluminum chips. Subsequent from this, the optimum of quenching and aging time and also the mechanical and physical properties were studied . In this study, the surface morphology on the specimen shows a positive results through the length of porous become smaller. The best porosity, density and water absorption is 1.95%, 2.55 g/cm^3 and 0.77 %. On the micro-hardness Vickers, the increasing percentage of the micro-hardness is about 19% from a preference value. Meanwhile, for the compression strength the increasing percentage of the compression strength is 17% also from a preference value. From all data were obtain, the optimum quenching and aging time is 8 hours quenching and 10 hours of aging. With this optimum, the reducing of energy consumptions and cost will be obtain.

ABSTRAK

Pada masa kini, penggunaan aluminium ini dipergunakan secara meluas. Proses kitar semula diperlukan untuk menyahut seruan kerajaan bagi kempen bumi hijau kerana kekurangan sumber mineral yang terdapat di bumi. Kaedah kitar semula secara langsung adalah salah satu kaedah kitar semula bagi mengurangkan kos dan penggunaan tenaga. Tujuan kajian ini adalah untuk menentukan kesan-kesan terhadap penlidapkejut dan penuaan bagi sifat mekanikal dan fizikal keatas cip aluminium AA6061 yang dikitar semula. Selepas itu, masa optimum bagi penglidapkejut dan penuaan serta sifat mekanikal dan fizikal dikaji. Dalam kajian ini, morfologi permukaan pada spesimen menunjukkan keputusan yang positif melalui panjang sesebuah keliangan menjadi lebih kecil. Nilai terbaik bagi keliangan, ketumpatan dan penyerapan air adalah 1.95%, 2.55 g /cm^3 dan 0.77%. Pada kekerasan micro Vickers, peningkatan peratuans kekerasan mikro adalah kira-kira 19% daripada nilai rujukan kekerasan micro. Sementara itu, untuk kekuatan mampatan, peratusan peningkatan kekuatan mampatan adalah 17% juga dari nilai rujukan kekuatan mampatan. Dari semua data yang diperolehi, masa optimum bagi pelindapkejutan dan penuaan adalah 8 jam bagi pelindapkejutan dan 10 jam bagi penuaan. Dengan optimum ini, pengurangan penggunaan tenaga dan kos akan diperolehi.

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LIST OF EQUATION

LIST OF SYMBOL AND ABREVIATION

°	-	Degree
%	-	Percent
°C	-	Celsius
μm	-	Micrometer
FESEM	-	Field Emission Scanning Electron Microscope
SEM	-	Scanning Electron Microscope
EDX	-	Electron Dispersive X-Ray
OM	-	Optical Microscope
RPM	-	Rotation Per Minute
XRD	-	X- Ray Diffraction
Wd	-	Dry weight
Ws	-	Suspended Weight
Ww	-	Wet weight
θ	-	Degree
ρ	-	Density
Wt	-	Weightage
MPa	-	Mega Pascal
ASTM	-	American Standard Testing Material

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CHAPTER 1

INTRODUCTION

1.1 Background study

Aluminium is a natural mineral that can be abundantly found on earth. There are so many usages of aluminium. Nowadays, aluminium is used worldwide. In the state of usage of aluminium, every country in a world used aluminium in their product. Many products were made of aluminium such as cans, automotive parts, electronic parts (certain product) and household product.

Figure 1.1: Global Old Scrap Recycled (BEN report, 2015)

They were 50.2 million tons of aggregate essential aluminium utilization on the world in 2013. China is the principle client of essential aluminium around the world, with 23.2 mil tons in 2013. North America (5.5 mil tons) and Europe (7.2 mil tons) have been the key districts for the utilization of essential aluminium (The European aluminium Association, 2013). These are mostly because of the outstanding application of aluminium on the world. Be that as it may, absence of control has caused the primary resource to gradually decline and caused numerous contamination impacts to nature. Aluminium is the most intensely devoured nonferrous metal on the planet, with the present yearly utilization at 24 million tons. Around 75% of this total volume (18 million tons) is essential aluminium (that is, separated from mineral) instead of optional aluminium which is gotten from scrap metal preparing (Totten & MacKenzie, 2003).

Aluminium is encountering an expanding accomplishment in different modern segments including automotive, building, packaging and household unit item. The expanding request from both expert and private buyers exhibits the utility of aluminium in regular day to day existence and the expanding of the aluminium is significance in the aluminium industries. In a worldwide setting, Europe has developed to be one of the world's biggest assembling base for the aluminium business attributable to substantial large-scale manufacturing limits over the European nations. In 2010, Europe remained the second real maker of essential aluminium and its aluminium creation expanded around 7% out of 2010 contrasted with the earlier year (Global Information Premium Market Research Report, 2011).

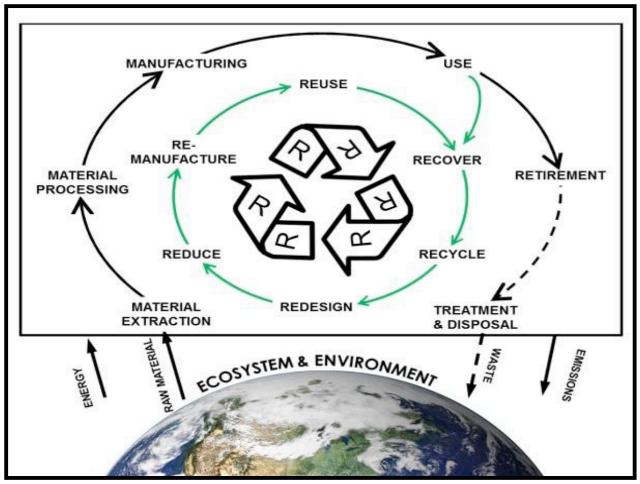

Figure 1.2: Close-loop product life-cycle system in 6R approach (Jayal et al., 2010).

Recently, there are increasing number of products were made from aluminium which lead to more generation of waste called aluminium chips. In the case of that, the waste from the product of aluminium must be reused,. The aluminium is a natural source (mineral). In order to fabricate the aluminium-based product, it need to go through the machining process at which in this stage that more waste are produced, Hence, in effort towards green environment, these wastes are ought to be recycled. . There are so many methods that can be used to recycle the aluminium chip.

Especially aluminium machining chips are a standout amongst the rest of the difficult type of aluminium scrap to reuse by re-liquefying. The oxidation of the material is intensified because of the high surface to volume ratio of the chips (Haase & Tekkaya, 2014). An alternative way to deal with the issue of material loss is by re-melting the aluminium chips and to additionally enhance the energy balance of the aluminium product is the immediate change of aluminium amalgam machining chips into completed or semi-finished items by hot extrusion which were first displayed and patented by Stern (1945). In this procedure, the chips are compacted to chip-based billets and extruded in respect to a customary hot extrusion press to the chip-based extrusion. Various types of aluminium chips can be reused by the means of hot extrusion such as turning chips or processing chips (Haase & Tekkaya, 2014). As a wide range of aluminium chips are normally secured by an oxide layer, the extensive plastic twisting (for instance strain) and compressive stress (for example pressure) must influence the chips amid the extrusion procedure so as to break the oxide layers and to enable contact between surfaces of pure metal (Gronostajski, Chmura, & Gronostajski, 2006). Those requirements for the extrusion of chips are in accordance with the study done by Bay (1979), who proposed a theory for a cold pressure welding. His study showed that by the process of cold pressure welding of aluminium includes the expansion of the surface, the mechanisms of fracture of a work-hardened surface layer, and finally the pressing of the material around the particles of the cracked hard surface layer (Haase & Tekkaya, 2014).

Based on Samuel's study, there are two type of recycled methods which are conventional and direct method. The new technique is characterised by fewer steps, a higher efficiency of recovery, and low generation of new scrap. The conventional process produces about 52%, whereas the direct conversion process introduced here produces about 96% of the extruded products (Samuel, 2003).

1.2 Problem statement

Aluminium is the most abundant metal in the earth's crust and most widely used material after steel. Figure 1.3 shows that in the year 1990, total aluminium production was around 28 million tonnes (with over 8 million tonnes recycled from scrap) and today the total is close to 56 million tonnes (with close to 18 million tonnes recycled from scrap). By year 2020, metal demand is projected to have increased to around 97 million tonnes (with around 31 million tonnes recycled from scrap). Today, around 50% of the scrap is old scrap (International Aluminum Institute, 2009).

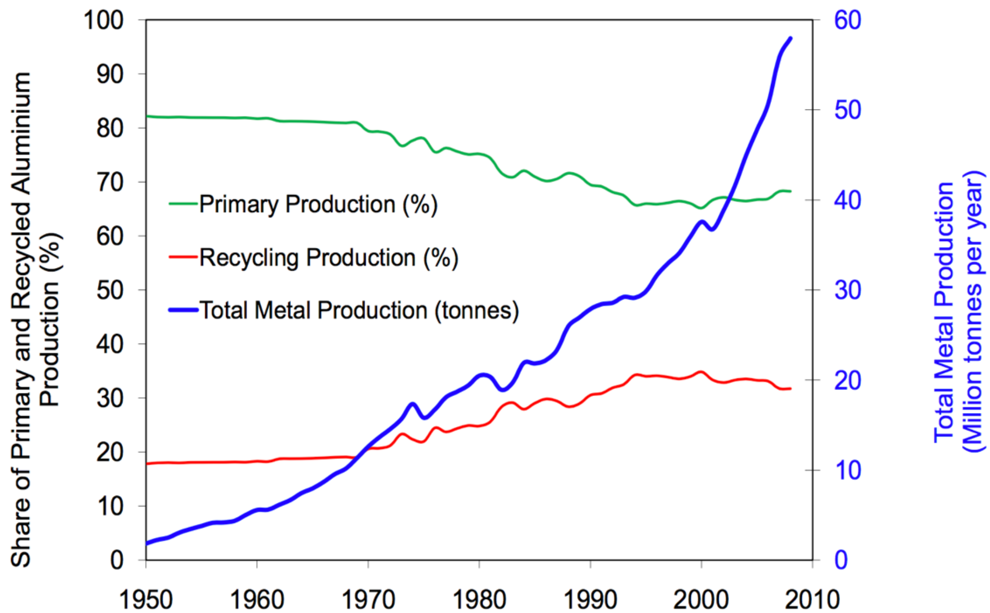

Figure 1.3: Global share of primary and recycled metal product (International Aluminum Institute, 2009).

There are 2 type of recycling methods which are conventional recycling method and direct recycling method. Figure 1.4 shows the flow chart of the recycling method. The conventional recycling of aluminium is recently less favourable, as the method requires high energy and large number of operations which led to cost increment. Instead of using melting techniques that use a very high temperature to reach the melting point, recycling of wrought aluminium alloys by solid-state is more preferable. High energy consumption for conventional aluminium recycling and subsequent refinement has been considered in previous studies. Initially, the solid-state recycling techniques have employed the powder metallurgy processes by (J.Z. Gronostajski, J.W. Kaczmar & H. Marciniak, 1997), followed by research from (Fogagnolo et al, 2003). Moreover, some of recycling techniques have been studied and show excellent mechanical responses by employing extrusion and powder metallurgy process (Yusuf, Lajis & Ahmad, 2017). This process chain requires a small amount of energy compared to conventional process chains, using only 5 – 6 GJ·ton^{-1}, which is 5 – 6% of that needed for the conventional process chain.

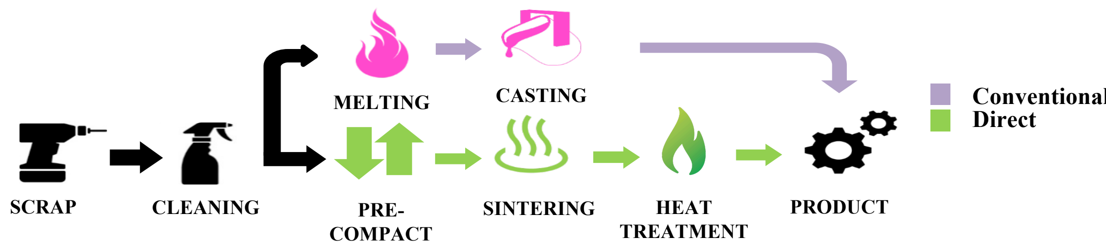

Figure 1.4: Flow chart of the recycling method (Yusuf et al., 2017).

The direct recycling method were also known as solid state recycling method. Solid-state recycling (cold compaction) has been proposed as a new recycling method for machined chips because its cost is relatively low, also favourable for environment protection and it is very important to obtain relatively high-density blocks from chips and optimize these process parameters during the solid-state recycling. The lowest energy consumption was introduced to optimize the cold compaction technology in both solid-state recycling means (Mustapa, Mahdi, & Lajis, 2016). Energy consumption during the hot compacted stage includes mechanical and endothermic power. Mechanical power is consumed when chips are inverted from the loose to compacted state by the hydrostatic machine. Endothermic power is also consumed when chips are heated (Ab Rahim, Lajis, & Ariffin, 2015).

In manufacturing of some aluminium product, a considerable amount of waste (chips) is produced. These chips are returned to the smelter and some of the waste is recovered or reutilized in the production process. The waste generation in the form of chips usually occurred at the finishing process but recycling of these chips are difficult due to their elongated spiral shape and micro size nature. Their surface area is relatively large and covered with oil emulsion which it is not effective for recycling through re-melting approach. Conventional recycling technique does not favour the environment much compared to the direct recycling technique (Kadir et al., 2017).

1.3 Objective

The objectives of this project are:

a) To determine the optimum time of quenching and aging on heat treatment of recycled aluminium chip AA6061.
b) To evaluate the mechanical and physical properties of recycled aluminium chip AA 6061.

1.4 Scope of studies

The scopes of this study focus on the following points.

a) Aluminium
   The material chosen on this research was aluminium AA 6061. High-speed milling machine was used to produce chips.
b) Preparation of specimen
   The recycled aluminium AA6061 chips were added with zinc stearate (1%) as a binder. The compaction load is 9 tons with holding time is 20 minutes.
c) Heat treatment
   Sintering was performed at 552 $^{\circ}$C with a heating rate 5 $^{\circ}$C/min and holding time 1 hour. Heat treatment is performed by using a quenching (530 $^{\circ}$C) and an aging (175 $^{\circ}$C) with different aging and quenching time (2, 4, 6, 8 and 10 hours). The medium of the quenching is water.
d) Mechanical and physical properties are analysed by:
   i. Density, porosity and water absorption – Archimedes Method
   ii. Microstructure –Optical Microscope (OM)
   iii. Hardness – Micro-hardness Machine Test (Vickers testing).
   iv. Compression test – Universal Testing Machine (UTM)

1.5 Thesis Outline

This section has been constructed to give details on the facts, observations, arguments, and procedures in order to meet its objectives. Five chapters including the introduction were composed to present the series of the logical thoughts of the thesis layout. The followings are the synopsis of each chapter.

1. Chapter 1: Introduction. Apart of providing an outline of the thesis, this chapter contains an overview of the research background, problem statement, objectives and scopes.
2. Chapter 2: Literature reviews. This chapter consists the background of aluminum, concept of metal matrix composite, application of the aluminum, recycled aluminum. On the preparation of specimen, the reviews on compaction, heat treatment, sintering, aging and quenching. This is followed by reviews on the related testing such as morphology, density, porosity, water absorption hardness test and compression test were made by previous researcher. It also has a summary of all reviews.
3. Chapter 3: Methodology. This chapter discussed the research methodology used to perform the study systematically. Its describes the materials and sample preparation on this research project. This research divide into two major parameter which is on various of aging and various of quenching. In this research also divide into two testing which is mechanical testing and physical testing. On mechanical testing consist of porosity, density, water absorption, micro-hardness Vickers and compression strength. While for physical testing consist of surface morphology.
4. Chapter 4: Result and discussion. This chapter discusses of the results from the experimental work. The result was obtained is from surface morphology analysis, porosity density, water absorption, micro-hardness Vickers analysis, and compression strength analysis. The discussion is about the finding of optimum result and also compared the result from the previous researcher.

REFERENCE

Ab Rahim, S. N., Lajis, M. A., & Ariffin, S. (2015). A Review on Recycling Aluminum Chips by Hot Extrusion Process. *Procedia CIRP*, *26*, 761-766.

Arockiasamy, A., German, R. M., Wang, P. T., Horstemeyer, M. F., Morgan, W., Park, S. J., & Otsuka, I. (2011). Sintering behaviour of Al-6061 powder produced by rapid solidification process. *Powder Metallurgy*, *54*(3), 354-359.

Ahmad, K. R., Lee, W. J., Zaki, R. M., Noor, M. M., Wahid, M. F. M., Shamsudin, S. R., & Jamaludin, S. B. (2007). The Microsructure and Properties of Aluminium Composite Reinforced with 65 μm Alumina Particles via Powder Metallurgy.

Akhil, K. T., Arul, S., & Sellamuthu, R. (2014). The effect of heat treatment and aging process on microstructure and mechanical properties of a356 aluminium alloy sections in casting. Procedia Engineering, 97, 1676–1682.

Khamis, S. S., Lajis, M. A., & Albert, R. A. O. (2015). A Sustainable Direct Recycling of Aluminum Chip (AA6061) in Hot Press Forging Employing Response Surface Methodology. *Procedia CIRP*, *26*, 477-481

Aykut Canakci, and Temel Varol, (2014), "Microstructure and properties of AA7075/Al–SiC composites fabricated using powder metallurgy and hot pressing." Powder Technology, pp 72-79.

Bansal, P., & Upadhyay, L. (2013). Experimental Investigations to Study Tool Wear During Turning of Alumina Reinforced Aluminium Composite. *Procedia Engineering*, *51*, 818-827.

Bello, S. A., Raheem, I. A., & Raji, N. K. (2015). "Study of tensile properties, fractography and morphology of aluminium (1xxx)/coconut shell micro particle composites". *Journal of King Saud University-Engineering Sciences*.

Blaz, L., Sugamata, M., Kaneko, J., Sobota, J., Wloch, G., Bochniak, W., & Kula, A. (2009). “Structure and properties of 6061+ 26mass% Si aluminum alloy produced via coupled rapid solidification and KOBO-extrusion of powder”. *Journal of Materials Processing Technology*, *209*(9), 4329-4336.

Canakci, A., & Varol, T. (2014). Microstructure and properties of AA7075/Al-SiC composites fabricated using powder metallurgy and hot pressing. Powder Technology, 268, 72–79.

Chan, B. L., & Lajis, M. A. (2015). Direct recycling of aluminium 6061 chipThrough cold compression. International Journal of Engineering and Technology, 15(4), 43–47.

Chiba, R., Nakamura, T., & Kuroda, M. (2011). Solid-state recycling of aluminium alloy swarf through cold profile extrusion and cold rolling. *Journal of Materials Processing Technology*, *211*(11), 1878-1887.

Chmura, W., & Gronostajski, J. (2000). Mechanical and tribological properties of aluminium-base composites produced by the recycling of chips. Journal *of Materials Processing Technology*, *106*(1), 23-27.

Cui, J., & Roven, H. J. (2010). Recycling of automotive aluminum. Transactions of Nonferrous Metals Society of China (English Edition), 20(11), 2057–2063.

Duflou, J. R., Tekkaya, A. E., Haase, M., Welo, T., Vanmeensel, K., Kellens, K., ... & Paraskevas, D. (2015). Environmental assessment of solid state recycling routes for aluminium alloys: Can solid state processes significantly reduce the environmental impact of aluminium recycling? *CIRP Annals-Manufacturing Technology*.

Fulcher, B. A., Leigh, D. K., & Watt, T. J. Comparison of Alsi$_{10}$mg And Al 6061 Processed Through Dmls.

Fogagnolo, J. B., Robert, M. H., & Torralba, J. M. (2006). Mechanically alloyed AlN particle-reinforced Al-6061 matrix composites: Powder processing, consolidation and mechanical strength and hardness of the as-extruded materials. *Materials Science and Engineering: A*, *426*(1), 85-94.

Fogagnolo, J. B., Ruiz-Navas, E. M., Simón, M. A., & Martinez, M. A. (2003). Recycling of aluminium alloy and aluminium matrix composite chips by pressing and hot extrusion. *Journal of Materials Processing Technology*,*143*, 792-795.

Fredenburg, D. A., Thadhani, N. N., & Vogler, T. J. (2010). Shock consolidation of nanocrystalline 6061-T6 aluminum powders. *Materials Science and Engineering: A*, *527*(15), 3349-3357.

G. B. Veeresh Kumar, C. S. P. Rao, N. Selvaraj, M. S. Bhagyashekar, (2010), " Studies on Al6061-SiC and Al7075-Al_2O_3 Metal Matrix Composites.", Journal of Minerals & Materials Characterization & Engineering, Vol. 9, No.1, pp.43-55.

Global Information Premium Market Research Report, (2011), European Aluminium Market Analysis. RNCOS E-Services Pvt.Ltd. Retrieved from http://www.giiresearch.com/report/rnc207190-european-aluminium-market-analysis.html.

Gökçe, A., & Fındık, F. (2008). Mechanical and physical properties of sintered aluminum powders. *Journal of achievements in materials and manufacturing engineering*, *30*(2), 157-164.

Gronostajski, J., Chmura, W., & Gronostajski, Z. (2006). Phases created during diffusion bonding of aluminium and aluminium bronze chips. *Journal of Achievements in Materials and Manufacturing Engineering*, *19*(1), 32-37.

Gronostajski, J., Chmura, W., & Gronostajski, Z. (2002). Bearing materials obtained by recycling of aluminium and aluminium bronze chips. *Journal of materials processing technology*, *125*, 483-490

Gronostajski, J. Z., Marciniak, H., Matuszak, A., & Samuel, M. (2001). Aluminium–ferro-chromium composites produced by recycling of chips. *Journal of Materials Processing Technology*, *119*(1), 251-256.

Gronostajski, J., Marciniak, H., & Matuszak, A. (2000). New methods of aluminium and aluminium-alloy chips recycling. *Journal of materials processing technology*, *106*(1), 34-39.

Gronostajski, J., & Matuszak, A. (1999). The recycling of metals by plastic deformation: an example of recycling of aluminium and its alloys chips. *Journal of Materials Processing Technology*, *92*, 35-41.

Gronostajski, J. Z., Kaczmar, J. W., Marciniak, H., & Matuszak, A. (1998). Production of composites from Al and AlMg2 alloy chips. *Journal of Materials Processing Technology*, *77*(1), 37-41.

German, R. M. (1990). Powder injection molding, MPIF. *Princeton, New Jersey*.

Güley, V., Güzel, A., Jäger, A., Khalifa, N. B., Tekkaya, A. E., & Misiolek, W. Z. (2013). Effect of die design on the welding quality during solid state recycling of AA6060 chips by hot extrusion. *Materials Science and Engineering: A*, *574*, 163-175.

Guluzade, R., Avcı, A., Demirci, M. T., & Erkendirci, Ö. F. (2013). Fracture toughness of recycled AISI 1040 steel chip reinforced AlMg1SiCu aluminum chip composites. *Materials & Design*, *52*, 345-352.

Haase, M., & Tekkaya, A. E. (2015). Cold extrusion of hot extruded aluminum chips. *Journal of Materials Processing Technology*, *217*, 356-367.

Haase, M., & Tekkaya, A. E. (2014). Recycling of aluminum chips by hot extrusion with subsequent cold extrusion. *Procedia Engineering*, *81*, 652-657.

Haase, M., Khalifa, N. B., Tekkaya, A. E., & Misiolek, W. Z. (2012). Improving mechanical properties of chip-based aluminum extrudates by integrated extrusion and equal channel angular pressing (iECAP). *Materials Science and Engineering: A*, *539*, 194-204

Huang Y. C., Yan, X. Y., and Tao Qiu, T., (2016), "Microstructure and mechanical properties of cryo-rolled AA6061 Al alloy.", Transaction of Nonferrous Metal Society of China, pp 12-18.

Hossein-Zadeh, M., Mirzaee, O., & Saidi, P. (2014). Structural and mechanical characterization of Al-based composite reinforced with heat treated Al_2O_3 particles. *Materials & Design*, *54*, 245-250.

Javdani, A., Pouyafar, V., Ameli, A., & Volinsky, A. A. (2016). Blended powder semisolid forming of Al7075/Al2O3 composites: Investigation of microstructure and mechanical properties. Materials and Design, 109, 57–67.

Jayal, A. D., Badurdeen, F., Dillon, O. W., & Jawahir, I. S. (2010). Sustainable manufacturing: Modeling and optimization challenges at the product, process and system levels. *CIRP Journal of Manufacturing Science and Technology*, *2*(3), 144-152.

Jin, P. P., Geng, C. H. E. N., Li, H. A. N., & Wang, J. H. (2014). Dry sliding friction and wear behaviors of $Mg_2B_2O_5$ whisker reinforced 6061Al matrix composites. *Transactions of Nonferrous Metals Society of China*, *24*(1), 49-57.

Jirang, C. U. I., & Roven, H. J. (2010). Recycling of automotive aluminum.*Transactions of Nonferrous Metals Society of China*, *20*(11), 2057-2063.

Kadir, M. I. A., Mustapa, M. S., Latif, N. A., & Mahdi, A. S. (2017). Microstructural Analysis and Mechanical Properties of Direct Recycling Aluminium Chips AA6061/Al Powder Fabricated by Uniaxial Cold Compaction Technique. Procedia Engineering, 184, 687–694.

Katharina Strobel, Matthew D. H. L., Mark A. E., Lisa Sweet, (2016), "Effects of quench rate and natural ageing on the age hardening behavior of aluminium alloy AA6060.", Elsevier, pp 43-52

Karl Ulrich Kainer, Metal Matrix Composites. Custom-made Materials for Automotive and Aerospace Engineering, retrieve from http://www.wiley-vch.de/books/sample/3527313605_c01.pdf.

Kök, M. (2006). Abrasive wear of Al 2 O 3 particle reinforced 2024 aluminium alloy composites fabricated by vortex method. *Composites Part A: Applied Science and Manufacturing*, *37*(3), 457-464.

Kök, M., & Özdin, K. (2007). Wear resistance of aluminium alloy and its composites reinforced by Al_2O_3 particles. *Journal of Materials Processing Technology*, *183*(2), 301-309.

Kumar, G. B. V., Rao, C. S. P., Selvaraj, N., & Bhagyashekar, M. S. (2010). Studies on Al6061-SiC and Al7075-Al_2O_3 Metal Matrix Composites. Journal of Minerals & Materials Characterization & Engineering, 9(1), 43–55. https://doi.org/10.4236/jmmce.2010.91004

Mahdi, A.H, Mustapa, M. S., Lajis, M. A., Rashid, M. W. A.,(2015), "Effect Of Compaction Pressure On Mechanical Properties Of Aluminium Particle Sizes AA6061 Through Powder Metallurgical Process" Journal of Engineering and Applied Sciences, 2015 , ISSN 1819-6608

Mahdi, A.H, Mustapa, M. S., Lajis, M. A., Rashid, M. W. A.,(2015), "Effect Of Holding Time On Mechanical Properties Of Recycling Aluminium Alloy AA6061 Through Ball Mill Process" International Journal of Mechanical Engineering and Technology (IJMET) Volume 6, Issue 9, Sep 2015, pp. 133-142

Mahdi, A.H, Mustapa, M. S., Lajis, M. A., Rashid, M. W. A.,(2015), "Effect of Compaction Pressure on Physical Properties of Milled Aluminium Chip (AA6061)" International Journal of Science and Research (IJSR) ISSN (Online): 2319-7064

Mahdi, A.H, Mustapa, M. S., Lajis, M. A., Rashid, M. W. A.,(2016), "The effect of cold compacting parameters for producing recycles Aluminum by milling process," ARPN Journal of Engineering and Applied Sciences, Vol. 11, No. 10, May 2016, pp. 6465-6471

Mahdi, A.H, Mustapa, M. S., Abdul L. M. Tobi and I. Zaman,(2016), "Micro-Hardness And Compression Strength Of Particle Sizes Recycling Aluminium Alloy Aa6061 Using Powder Metallurgy Method.", ICME 2016 International Conference on Engineering Design and Analysis.

Mahdi, A.H, Mohd Sukri Mustapa, M. S., Lajis, M. A., Rashid, M. W. A.,(2016), "Effect Of Sintering Temperature On Compression Strength And Microhardness Of Recycling Aluminium Alloy Aa6061 Through Ball Mill Process," ARPN Journal of Engineering and Applied Sciences, Vol. 11, No. 1, January 2016, pp. 659-665

Mashhadi, H. A., Moloodi, A., Golestanipour, M., & Karimi, E. Z. V. (2009). Recycling of aluminium alloy turning scrap via cold pressing and melting with salt flux. *journal of materials processing technology*, *209*(7), 3138-3142.

Oscar Iribarren, Aluminium Chips Recycling High Efficiency and Recovery on Aluminium Foundries retrieve from http://www.aluplanet.com/documenti/InfoAlluminio/InfoInsertecENG.pdf

Ondracek, G. (1994). *Werkstoffkunde: Leitfaden für Studium und Praxis*. expert verlag.

Puga, H., Barbosa, J., Soares, D., Silva, F., & Ribeiro, S. (2009). Recycling of aluminium swarf by direct incorporation in aluminium melts. *Journal of Materials Processing Technology*, *209*(11), 5195-5203.

Reddy, A. C., & Zitoun, E. (2010). Matrix Al-alloys for silicon carbide particle reinforced metal matrix composites. *Indian journal of Science and Technology*, *3*(12), 1184-1187.

Samuel, M. (2003). A new technique for recycling aluminium scrap. Journal of Materials Processing Technology, 135(1), 117–124.

Schaffer, G. B., Huo, S. H., Drennan, J., & Auchterlonie, G. J. (2001). The effect of trace elements on the sintering of an Al–Zn–Mg–Cu alloy. *Acta materialia*, *49*(14), 2671-2678.

Schlesinger, M. E. (2013). *Aluminum recycling*. CRC Press.2007.

Sekhar, R., & Singh, T. P. (2015). Mechanisms in turning of metal matrix composites: a review. *Journal of Materials Research and Technology*, *4*(2), 197-207.

Sercombe, T. B. (2003). On the sintering of uncompacted, pre-alloyed Al powder alloys. *Materials Science and Engineering: A*, *341*(1), 163-168.

Shi, Q., Tse, Y. Y., & Higginson, R. L. (2015). Effects of processing parameters on relative density, microhardness and microstructure of recycled Ti–6Al–4V from machining chips produced by equal channel angular pressing. *Materials Science and Engineering: A*, *651*, 248-258.

Singh, J., & Chauhan, A. (2015). Overview of wear performance of aluminium matrix composites reinforced with ceramic materials under the influence of controllable variables. *Ceramics International*, *42*(1), 56-81.

Singla, M., Dwivedi, D. D., Singh, L., & Chawla, V. (2009). Development of aluminium based silicon carbide particulate metal matrix composite. *Journal of Minerals and Materials Characterization and Engineering*, *8*(06), 455.

Showaiter, N., & Youseffi, M. (2008). Compaction, sintering and mechanical properties of elemental 6061 Al powder with and without sintering aids. *Materials & Design*, *29*(4), 752-762.

Strobel, K., Lay, M. D. H., Easton, M. A., Sweet, L., Zhu, S., Parson, N. C., & Hill, A. J. (2016). Effects of quench rate and natural ageing on the age hardening behaviour of aluminium alloy AA6060. Materials Characterization, 111, 43–52.

The European Aluminium Association (2013*). Primary Aluminium consumption 2011-2013*. Brussels: European Aluminium Association. Van der Geer J, Hanraads JAJ, Lupton RA. The art of writing a scientific article. J Sci Commun 2000;163:51-9.

Technology, J., & Diefendorf, R. J. (1990). Aerospace Industry is Major Focus of Composites Research in Japan, (May), 15–16.

Trevino, M., Mercado-Solis, R. D., Colas, R., Perez, A., Talamantes, J., & Velasco, A. (2013). Erosive wear of plasma electrolytic oxidation layers on aluminium alloy 6061. *Wear*, *301*(1), 434-441.

Totten, G. E., & MacKenzie, D. S. (Eds.). (2003). *Handbook of Aluminum: Vol. 1: Physical Metallurgy and Processes* (Vol. 1). CRC Press.

TechTrends, International Reports on Advanced Technologies: Metal Matrix Composites: Technology and Industrial Application, Innovation 128, Paris (1990)

Wang, H. Q., Sun, W. L., & Xing, Y. Q. (2013). Microstructure Analysis on 6061 Aluminum Alloy after Casting and Diffuses Annealing Process. *Physics Procedia*, *50*, 68-75.

Yazdian, N., Karimzadeh, F., Tavoosi, M., (2010). "Microstructural evolution of nanostructure 7075 aluminum alloy during isothermal annealing". J. Alloys Compd. 493, 137-141.

Zichuan Lu, NingxiaWei, Peng Li, Chunhuan Guo, Fengchun Jiang, (2016), "Microstructure and mechanical properties of intermetallic Al_3T_i alloy with residual aluminum.", Materials and Design 110, pp. 466–474

Zapata, W. C., Tomiyama, M., & Donadon, M. V. (1997). Reciclagem de Cavacos de Usinagem de Alumınio via Metalurgia do Pó. *Fabricação de Compósitos, VI Seminário de Tecnologia da Indústria do Alumınio, São Paulo*, 227-290.